

DESIGN CRITERIA REPORT

PRODUCT 9.1 Final



HONOLULU HIGH-CAPACITY TRANSIT CORRIDOR **ALTERNATIVES ANALYSIS / DRAFT ENVIRONMENTAL IMPACT STATEMENT**

prepared for:
City and County of Honolulu



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Design Criteria Honolulu High-Capacity Transit Corridor Project

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Summary

This report documents the design criteria that were used for preparation of the conceptual plans, profiles, stations, and guideway structures for the Honolulu High-Capacity Transit Corridor Project (HHCTCP). The criteria were developed to provide a uniform design that meets appropriate standards, provides satisfactory levels of service, and supports the capital cost estimates.

Four alternatives were evaluated in the Alternatives Analysis (AA) report for the HHCTCP. They were developed through a screening process that considered alternatives identified through previous transit studies, a field review of the study corridor, an analysis of current housing and employment data for the corridor, a literature review of technology modes, work completed by the O'ahu Metropolitan Planning Organization (OMPO) for its Draft 2030 Regional Transportation Plan, and public and agency comments received during a formal project scoping process held in accordance with requirements of the National Environmental Policy Act (NEPA) and the Hawai'i EIS Law (Chapter 343, Hawai'i Revised Statutes).

The four alternatives are described in detail in the *Honolulu High-Capacity Transit Corridor Project Alternatives Analysis Definition of Alternatives Report* (DTS, 2006a). The alternatives identified for evaluation in the AA report are as follows:

- No Build Alternative
- Transportation System Management Alternative
- Managed Lane Alternative
- Fixed Guideway Alternative

During the analysis phase of the project, there were five (5) different technologies considered. Among them is the Bus Rapid Transit, and the four (4) Fixed Guideway Technologies; Light Rail Transit (LRT), Rapid Rail Transit (RRT), Monorail, and Magnetic Levitation or Maglev, as is commonly known.

In December 2006 Honolulu's City Council selected the Fixed Guideway Alternative as the Locally-Preferred Alternative (LPA). City Council then approved, in February 2007, a Minimum Operable Segment that defines the first project to be constructed.

Design criteria for the 5 technologies are described in this report. Chapter 1 describes criteria for Bus Rapid Transit that is considered for the Managed Lane Alternative. This alternative includes a two-lane, grade-separated facility that extends between Waipahu and Downtown Honolulu. Chapters 2 through 5 describe typical design criteria derived from recent comparable projects for 4 technology options being considered for the Fixed Guideway Alternative: Light Rail, Rapid Rail, Monorail, and Maglev. This alternative consists primarily of elevated guideway, but has at-grade and underground sections on some of the alignment options. With consideration for the geographic constraints in the Honolulu environment, appropriate geometric design layout criteria to be used during conceptual design of the fixed guideway were selected. The selected design criteria are summarized in Chapter 6.

The technology for the Fixed Guideway Alternative will be determined during the NEPA phase of the project. The design criteria noted in Chapter 6 may need to be revised during the preliminary engineering phase, which runs parallel to NEPA, after the actual technology option is selected.

This chapter covers the required functional, operational and physical characteristics of the BRT vehicles for use in the design of the Managed Lane Alternative.

Vehicle Characteristics

The vehicles to be operated on the managed lane facilities will vary depending on the level of service planned. Therefore, the facilities will be designed to accommodate the following types of vehicle:

- **Standard Transit Bus:** The primary vehicle to utilize the managed lane facility will be the standard 40 foot transit bus. Smaller transit vehicles (such as 35 foot and 25 foot buses) will automatically be accommodated by this design standard. See Figure 1-1 for dimensions and design template.
- **Articulated Bus:** Articulated Buses will be used on heavier volume routes and must be accommodated by the managed lane facilities. See Figure 1-2 for dimensions and design template.

Vehicles will be designed for passenger comfort with comfortable seating, air conditioning, and adequate interior lighting suitable for reading comfort and safety.

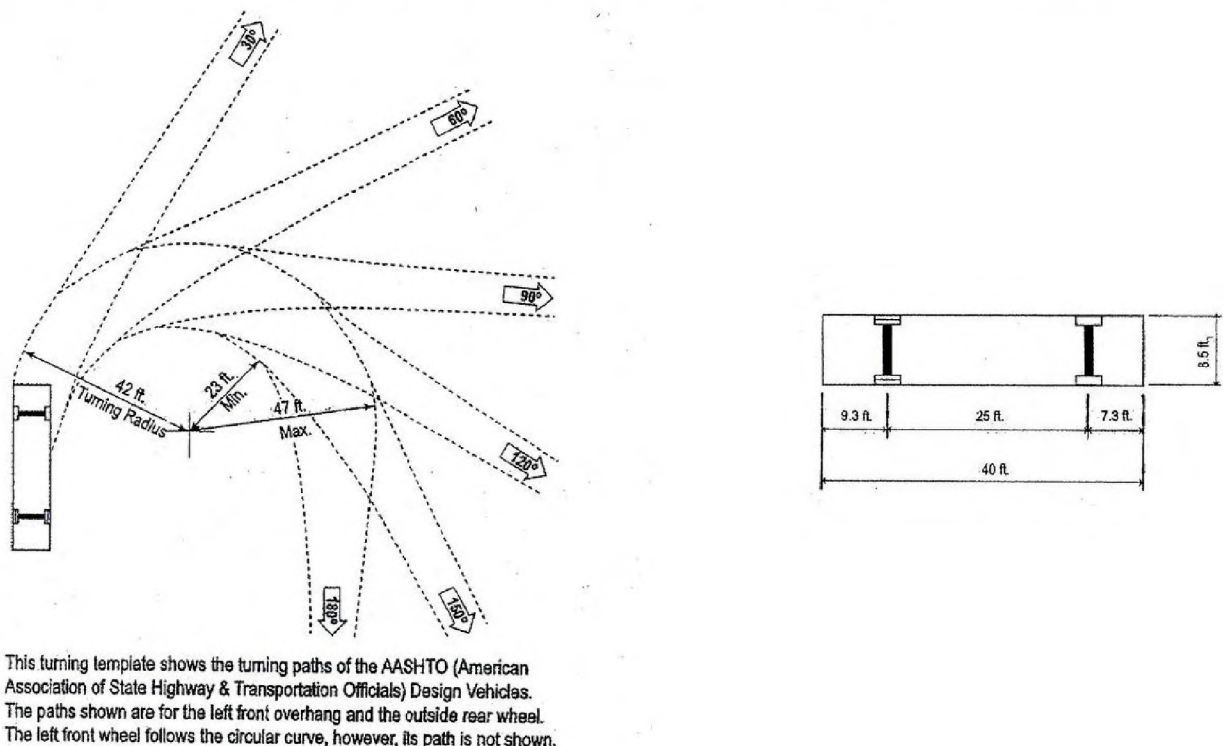
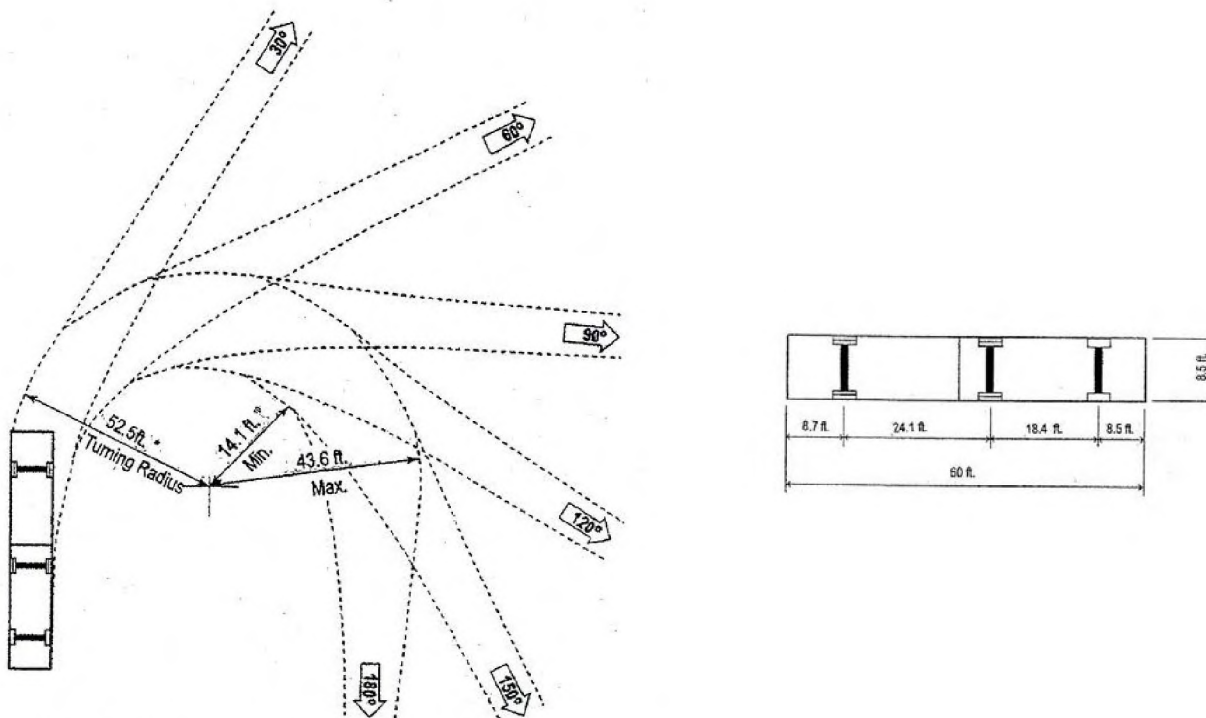


Figure 1-1: Design Template of 40 Foot Bus

Source: National Cooperative Highway Research Program Report 414, HOV Systems Manual, 1998

Notes: Not to scale



This turning template shows the turning paths of the AASHTO (American Association of State Highway & Transportation Officials) Design Vehicles. The paths shown are for the left front overhang and the outside rear wheel. The left front wheel follows the circular curve, however, its path is not shown.

Figure 1-2: Design Template of Articulated Bus

Source: National Cooperative Highway Research Program Report 414, HOV Systems Manual, 1998

Notes: Not to scale

These values are being re-evaluated by AASHTO

Basic Dimensions

The Standard Transit Bus is normally 40 feet long, 8 feet 6 inches wide and 10 feet 9 inches high. A vehicle typically weighs from 25,500 pounds empty or 36,500 pounds or more fully loaded. Each vehicle is generally designed to accommodate 45 passengers seated and 15 to 30 standees depending on the design standard used for the number of passenger per square foot.

The Articulated Bus is normally 60 feet long, 8 feet 6 inches wide and 10 feet 10 inches high. A vehicle typically weighs from 39,574 pounds empty to 57,100 pounds or more fully loaded. Each vehicle is generally designed to accommodate 70 to 76 passengers seated and 35 or more standees depending on the design standard used for the number of passengers per square foot.

Vehicle Performance

The Standard Transit Bus generally has a maximum operating speed of 65 miles per hour (mph) and usually operates at the maximum cruising speed of the posted speed limit. Typical vehicle acceleration for normally loaded vehicles will be approximately 2 mph per second. Typical deceleration will be 2.5 mph per second.

Alignment Design

Alignment design will be based on vehicle clearances established to ensure rider comfort, safety, and operational efficiency. Due to right-of-way limitations and roadway constraints in the corridor, it may not be possible to meet all the desirable standards in the American Association of State Highway and Transportation Officials (AASHTO), *A Policy on Geometric Design of Highways and Streets*, 1994. This is sometimes the case with projects that involve modifications to existing facilities and does not preclude these projects from being designed to safe and acceptable standards.

AASHTO, in cooperation with the Federal Highway Administration (FHWA), sponsored a research project that produced design guidelines for high occupancy vehicle and bus rapid transit facilities. The product of this research, the *Guide for High-Occupancy Vehicle (HOV) Facilities*, 2004, includes suggested reduced design standards when desired design standards cannot be met. These reduced design standards have been accepted by FHWA on other projects through design exceptions. For the most part, these design exceptions would be for reduced lane widths or the use of shoulder lanes for traffic lanes.

The primary component of the managed lane facility is an elevated, two-lane roadway that extends longer than 10 miles with direct connections to the H-1 and H-2 freeways. As such, it would need to be designed as a high-speed facility with a minimum design speed of 60 mph. Freeway access ramps would be designed with a minimum design speed of 50 mph.

The following design parameters are based on comparable bus priority and multiple occupancy vehicle facilities and are intended as guidelines for the conceptual design of the HHCTCP Managed Lane Alternative.

Lane and Shoulder Widths

The following lane and shoulder widths are typical; other widths may be used if approved by the governing agencies:

- Lane width in freeway (desired): 12 feet
- Lane width in freeway (reduced): 11 feet
- Lane width in arterial street (desired): 12 feet
- Lane width in arterial street (reduced): 10 feet
- Freeway shoulder width (desired): 10 feet
- Freeway shoulder width (reduced): 2 feet

Vertical Clearances

The following minimum vertical clearances are typical:

- Minimum overhead clearance (desired): 17 feet 6 inches
- Minimum overhead clearance (reduced): 14 feet 6 inches

Horizontal Alignment

The horizontal alignment of the managed lane facility would follow the alignment of the freeway or the arterial street being retrofitted to accommodate the facility. Therefore, the freeway or street alignment, in general, will define the horizontal alignment. Minimum curve radii and other geometric criteria would be in accordance with AASHTO for the minimum design speeds previously mentioned.

Vertical Alignment

The vertical alignment of the managed lane facility would also be controlled by the alignment of the freeway or arterial street being retrofitted and would meet AASHTO guidelines.

Minimum Turning Path of Design Vehicles

The design for the managed lane facility would comply with the AASHTO design requirements for a 40 foot long Standard Transit Bus and a 60 foot long Articulated Bus, as described above. The minimum turning paths for these vehicles are shown in Figures I-1 and I-2, respectively.

Retrofit Design

The managed lane would be retrofitted into existing freeway and arterial environments. Therefore, design compromises may be required. For example, less than typical lateral clearances between managed lane or general traffic lanes and nearby fixed objects may be required. Inside shoulders may need to be eliminated. Transition lengths may be held to minimum values. In each instance, careful consideration must be given to the safety and operational aspects of the design, and minimum design values or waivers pursued with great care.

Station Design

The station is to be designed to accommodate the expected patron demand on the platform comfortably under normal operating conditions and will be governed by the following factors:

- Passenger volume
- Fire/life safety requirements
- Type of bus and service planned
- Pedestrian access
- Accessibility for individuals with disabilities
- Local site conditions
- Joint development opportunity

Platform Configuration

Platforms are generally to be designed to accommodate low-floor and normal floor height buses. Elevator, escalator and stair surge zones are to be free of any and all obstructions. The elevator surge zone is defined as a 10 foot square area in front of the elevator door. Stair and/or escalator surge zones are to be 15 feet long (measured from the end of handrail) and 5 feet wider in each direction than the stairs and/or escalator.

Station canopy supports located on the platform are to be located away from vehicle doors during station stops to minimize congestion. Columns/canopy supports located beyond 10 feet have no restriction in their placement.

Platform Size

Platforms are to be sized based on peak hour demand and accommodate peak 15-minute volumes excluding edge strips. The length of the platform would be a minimum of 200 feet.

The widths of platforms will generally have a desirable dimension of 12 feet to 14 feet and are to be verified by the designer based on actual conditions, with 8 feet to be the minimum width considered. Wider platform widths are recommended wherever possible.

Platform widths are designed for a minimum number of pedestrian travel lanes required for exiting in addition to the platform edge strips, space between the edge of travel way and wall or railing and vertical circulation elements. Platform edge strips will be 2 feet wide and are to have a distinct tactile relief with color contrast with the vehicle floor and platform surface.

Structural Design

This section establishes the design criteria that are to be followed for design of managed lane structures. The selection for the type of structure will depend upon the characteristics of each particular site.

Items in this category include aerial structures, bridges, stations, retaining walls, buildings (including yard and shops), construction structures and miscellaneous structures.

The vehicular design load for the managed lane guideway structure would be AASHTO HS 20-44 loading.

Structures will be designed for seismic using normalized design response spectra developed by a qualified geotechnical engineer based on geologic, tectonic, seismological, and soil characteristics associated with the specific construction sites. The maximum base (unadjusted) effective peak acceleration is shown in Figure 1-3.

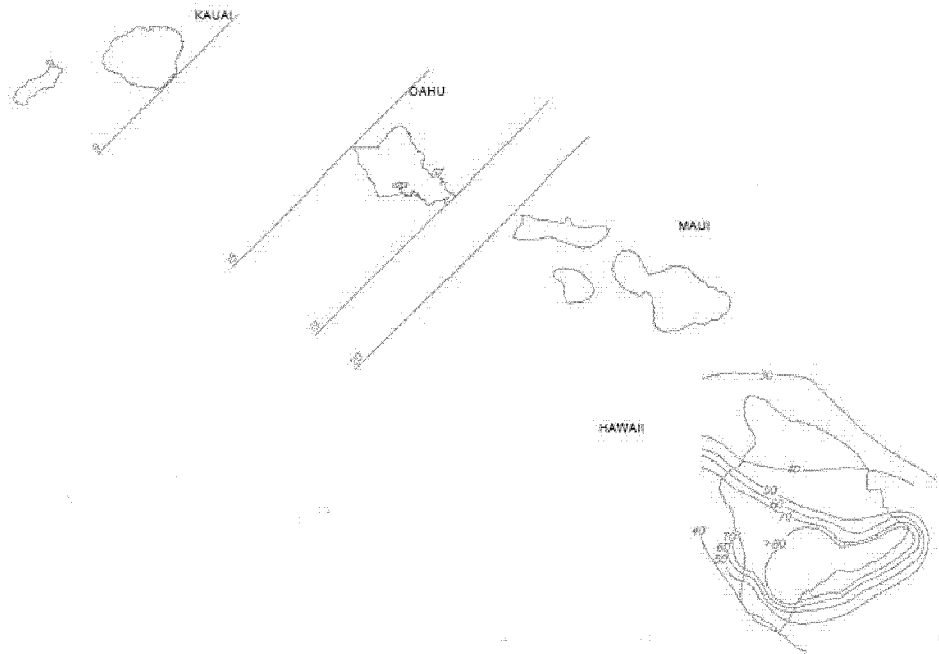


Figure 1-3: Acceleration Coefficients for Hawaii

The following codes and specifications are to be used in the design of structures:

- HDOT Bridge Standards including exceptions to American association of State Highway and Transportation Officials (AASHTO) standards and current seismic standards
- AASHTO LRFD Bridge Design Specifications, most recent edition with current revisions.
- AASHTO Standard Specifications for Structural Supports for Highway Signs and Luminaries and Traffic Signals, most recent edition
- AASHTO Manual for Maintenance Inspection of Bridges, most recent edition with current supplements
- Uniform Building Code, State of Hawaii, most recent edition

AASHTO Standards as modified by the state of Hawaii, Department of Transportation, Highways Division (HDOT) will be used. Design loads for bridges, tunnels, culverts, and retaining walls will be specified in the AASHTO Standard Specifications for Highway Bridges, supplemented by HDOT Specifications and these provisions for high occupancy vehicle facilities. In the case of conflict among these sources, HDOT provisions take precedence over AASHTO.

There is little structural difference for BRT than for standard AASHTO highway loading. An exception is the structural consequence of the impact forces applied to edge barrier, median barrier, and energy absorption systems that are finally chosen. Such decisions should be based on the actual vehicles using the guideway and the recommendations of

the National Transportation Safety Board, the Federal Highway Administration Office of Safety, and AASHTO RSDG-3-M, Roadside Design Guide, 3rd Edition.

In addition to barrier impact safety, noise criteria should be provided that determines the sound and light reflecting ability of the barriers. Also, structural criteria consideration should be given to the consequences of decisions made for the handling and protection of passengers near bus operations during their use of the safety walkways and during their emergency egress from the guideways.

If a trolley bus system is chosen employing external electric power both support of the catenary equipment and special stray current corrosion protection and isolation criteria will be required.

Four different technology options are being evaluated for the Fixed Guideway Alternative. This section covers the required functional, operational and physical characteristics of LRT Low Floor vehicles and their associated typical design criteria.

Vehicle Characteristics

Standard Low Floor LRT cars mount on and propel along the alignment using standard railroad rails that can easily be traversed by road vehicles when the track is at grade.

Basic Dimensions

- Length of vehicle to be: 90.0 to 94.0 feet over couplers
- Maximum width: 8 feet 9.5 inches over car body, 8 feet 11.7 inches over door threshold
- Maximum height: 12.0 feet, 8.0 inches (pantograph down)
- Pantograph operating range: 13 feet to 23 feet
- Door threshold: 14 inches above top-of-rail

Vehicle Performance

- Maximum operating speed: 65 miles per hour (mph)
- Acceleration: 3 mph per second
- Deceleration: 2.7 mph per second
- Weight, max: 97,500 pounds (fully loaded)

Overhead Contact System Characteristics

The Overhead Contact System (OCS) would utilize three possible configurations: Standard Depth Catenary, Low Profile Catenary, and Single Contact Wire. The OCS for all types will be supported by bracket arms or span guys attached to poles located either outside or between the tracks.

The nominal OCS voltage will be 750 V dc.

Basic dimensions for the OCS are outlined below:

- Contact wire height above top-of-rail:
 - 15 feet normal for fully exclusive ROW
 - 14 feet minimum for fully exclusive ROW
 - 18 feet minimum for mixed traffic
 - 23 feet at grade crossings
- Messenger wire height above top-of-rail:

- Standard depth 4 feet above contact wire
- Low profile 2 feet above contact wire
- Clearance center line of track to center of OCS pole:
 - Tangent track 7 feet 6 inches minimum
 - Tangent track 7 feet absolute minimum
 - Clearances for horizontal curves are greater

Alignment Design

Alignment design will be based on vehicle clearances and utilize horizontal and vertical curves established to ensure comfort, safety and operational efficiency.

The following design parameters are based on comparable LRT project facilities recently entering revenue service and are intended as guidelines for the conceptual design.

Guideway Widths

- Typical section at grade tangent track: see Figure 2-1
- Typical section aerial: see Figure 2-2

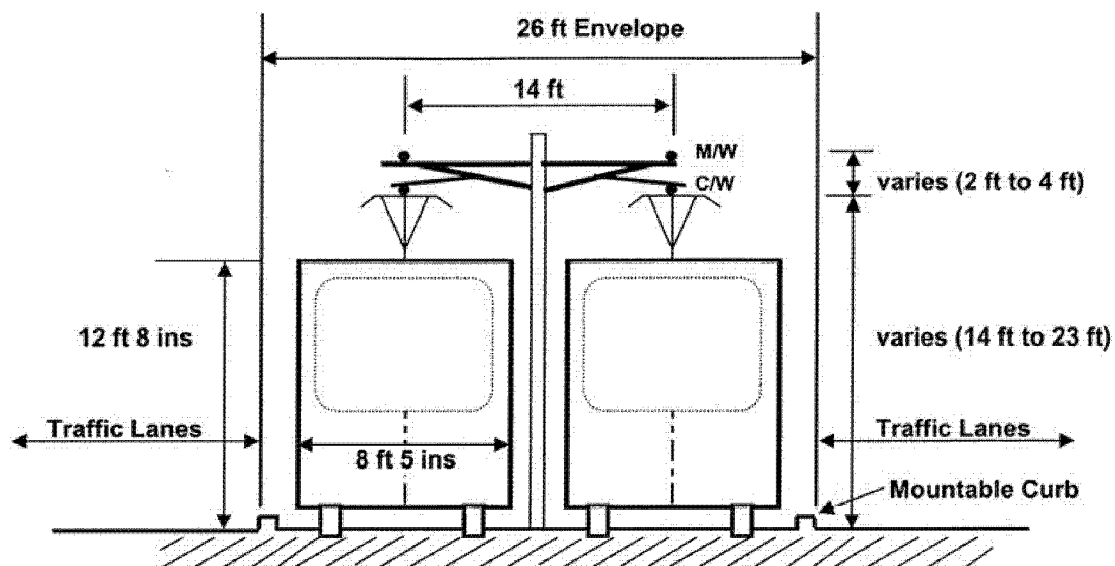


Figure 2-1: LRT At-Grade Guideway

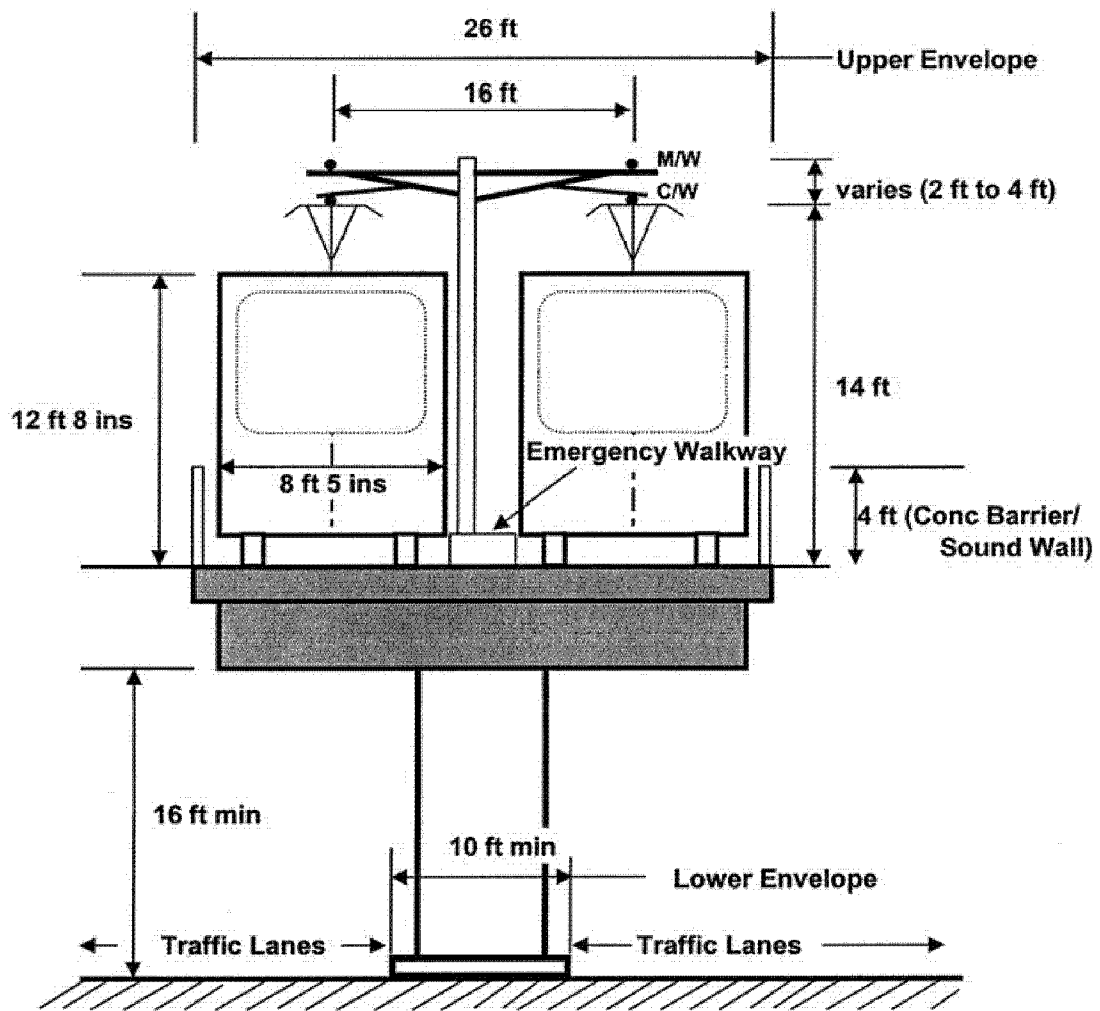


Figure 2-2: LRT Elevated Guideway

Horizontal Alignment and Superelevation

The parameters for the design of horizontal alignments shall be in accordance with the recommendations of the most current version of the Manual for Railway Engineering, published by the American Railway Engineering and Maintenance Association (AREMA) except as modified herein.

The horizontal alignment of mainline tracks shall consist of tangents joined to circular curves by spiral transition curves. Spiral curves need not be used in yard and service areas.

Curvature and superelevation shall be set to maximize design speed, which shall be set to equal or exceed the operating speed. Consideration should be given to the acceleration and deceleration characteristics of the LRT vehicle. When ever practical, the geometrics shall accommodate the maximum operating speed of 65 mph. Where the location of curves, station stop spacing, construction limitations and the performance characteristics

of the design LRT vehicle require the operating speed to be less than the maximum, the track geometrics shall suit the reduced speed.

Track Spacing

Track spacing will vary, depending on the type of construction used for the particular section. Minimum center-to-center track dimensions for open route parallel tracks shall be 15 feet. Increased center-to-center track dimensions will be required through curved sections. Center-to-center track dimensions for parallel tracks in station areas having center platforms will be dependant upon the width of the platform.

Superelevation

In the design of horizontal alignments, the allowable speed throughout the curved sections shall be determined by passenger comfort as related to superelevation. Superelevation is defined as the difference in inches between high rail and low rail.

Horizontal Curve Radius

The minimum curve radii (R) for the corresponding speed in mph are as follows:

- R = 850 feet for 25 mph
- R = 3,300 feet for 50 mph
- R = 5,500 feet for 60 mph

These values correspond to a total superelevation of 3 inches, which can be taken as 1-½ inches of actual superelevation with 1-½ inches of unbalance superelevation.

Vertical Alignment

The vertical profile shall represent the elevation of the top of the low rail.

Grades

The maximum sustained grade for mainline tracks shall be 3.0 percent; the absolute maximum sustained grade shall be 4.0 percent. For distances not greater than 500 feet, an absolute maximum grade of 7.0 percent may be used.

A minimum vertical tangent of 100 feet is required for mainline track. An absolute minimum of 40 feet is required for yard tracks.

Vertical Curvature

All changes in grade shall be connected by parabolic vertical curves.

- Minimum vertical curve:
 - Crest = $G1 - G2 * V * V / 25$ feet
 - Sag = $G1 - G2 * V * V / 40$ feet
- Maximum gradient: 7.0%

Clearance Requirements

Clearance Envelope

The clearance envelope is defined as the space occupied by the dynamic outline of the design of the LRT vehicle plus an additional running clearance of 2 inches around the dynamic outline.

Horizontal Clearances

Minimum horizontal clearances measured from the centerline of track shall be as follows:

- Adjacent parallel tracks: 14 feet centers, absolute minimum
- Retaining walls or continuous restrictions: 9 feet with provision made for safety walk; 6 feet 6 inches with no provision made for safety walk
- Fences parallel to track: 11 feet 6 inches
- Wall of cut-and-cover structure in subway: 8 feet 3 inches on side of safety walk; 6 feet 6 inches on side without safety walk

Vertical Clearances

Minimum vertical clearances, measured from top of high rail shall be as follows:

- Fixed structure in subway, cut-and-cover section, exclusive ROW: 16 feet
- Fixed structure in open, mixed traffic: 23 feet

Trackwork

“Trackwork”, as used in this section refers to standard trackwork and special trackwork including turnouts, crossovers, double crossovers, and track crossings.

Track materials and special trackwork shall be based generally upon the recommendations in the most current American Railway Engineering and Maintenance-of-Way Association (AREMA) Manuals for Engineering, the Portfolio Of Trackwork Plans and upon other generally accepted transit industry standards, practices and recommendations as appropriate to reflect the physical and operating characteristics of the system.

Track shall be designed to minimize levels of stray currents resulting from the use of the running rails as the negative return circuit for the traction current.

Track shall be designed to limit the noise and vibration transmission due to the passage of the transit vehicles.

Tracks shall be designed for the maximum degree of constructability and maintainability. Maximum accessibility should be provided to track components requiring frequent maintenance (i.e., special trackwork).

Track components design shall be standardized to the greatest possible extent to facilitate maintenance and minimize the inventory of materials.

Standard Type of Track Construction

There are two general classes of tracks:

1. Mainline tracks: tracks that carry revenue passengers.
2. Yard and secondary tracks: tracks that do not carry revenue passengers, such as tracks constructed for the purpose of storing, maintaining, or switching LRT vehicles.

Trackwork for these two general classes of track may be further classified into five basic types of standard trackwork:

1. Ballasted track
2. Direct-fixation track
3. Slab track
4. Shop track
5. Embedded track

Track Gauge

The standard track gauge shall be 4 feet 8-½ inches. Track gauge shall be measured perpendicular to the gauge sides of the heads of the rails at a distance of 5/8 inch below the tops of rails. Wider gauges shall be used in curves depending upon the degree of curvature.

Gauges for special trackwork shall be as recommended in AREA Portfolio of Trackwork Plans, except as modified to reflect the physical and operational characteristics of the system.

Station Design

The station design shall comply with relevant accessibility standards including the American with Disabilities Act (ADA). The layout of the station should promote a “user friendly” atmosphere with ease of use and route recognition the primary objective.

Station Capacity-Emergency Conditions: stations must meet the requirements for emergency evacuation as established by NFPA 101 and NFPA 130. These documents and any other applicable codes shall be used when determining the size of station exit stairs and other vertical circulation elements.

The station design will also be governed by the following factors:

- Passenger volume
- Fire/life safety requirements
- Integration with other modes of transportation
- Local site conditions
- Joint development opportunity

Platform Configuration

All station platforms shall be low level loading type, either center platform or side platform with a nominal 14 inches height above the top of the rail. To enhance security, platform entry points shall be clear of obstructions reducing visibility. Evenly distributed platform entry points produce system operational benefits. Platform edge pavers with a truncated dome pattern shall be provided and shall be consistent with the rules and regulations required by ADA.

The horizontal alignment at stations shall be tangent throughout the entire length of the platform. The tangent shall be extended beyond both ends of the platform a desired minimum of 75 feet.

Zero grade is desired in passenger stations. Special provisions may be necessary to maintain adequate drainage. The absolute maximum allowable grade through a passenger station shall be plus or minus 1.0 percent. Vertical curves shall not encroach within 82 feet of station platforms.

Platform Size

Station platforms shall be sized to accommodate site specific patronage projections. For platform sizing and means of egress, including emergency conditions, refer to NFPA 101 and NFPA 130.

- Platform widths-unless otherwise specified:
 - Center platform: 18 feet
 - Side platform: 14 feet
- Platform length for a typical:
 - Two LRT car set: 195 feet
 - Three LRT car set: 290 feet
 - Four LRT car set: 385 feet

Structural Design

Guideway structures that support light rail have the greatest potential for variance in structural criteria due to the vehicle design alternatives available. These include street level passenger loading and high platform passenger loading, multi-articulations and therefore numerous potential curve radii, and either pantograph or rail level electrification. For electrification, the alternate use of both pantograph and lower third rail on the same vehicle is also now possible.

The axle loads and spacing for a major currently operating LRT system are shown in Figure 2-3:

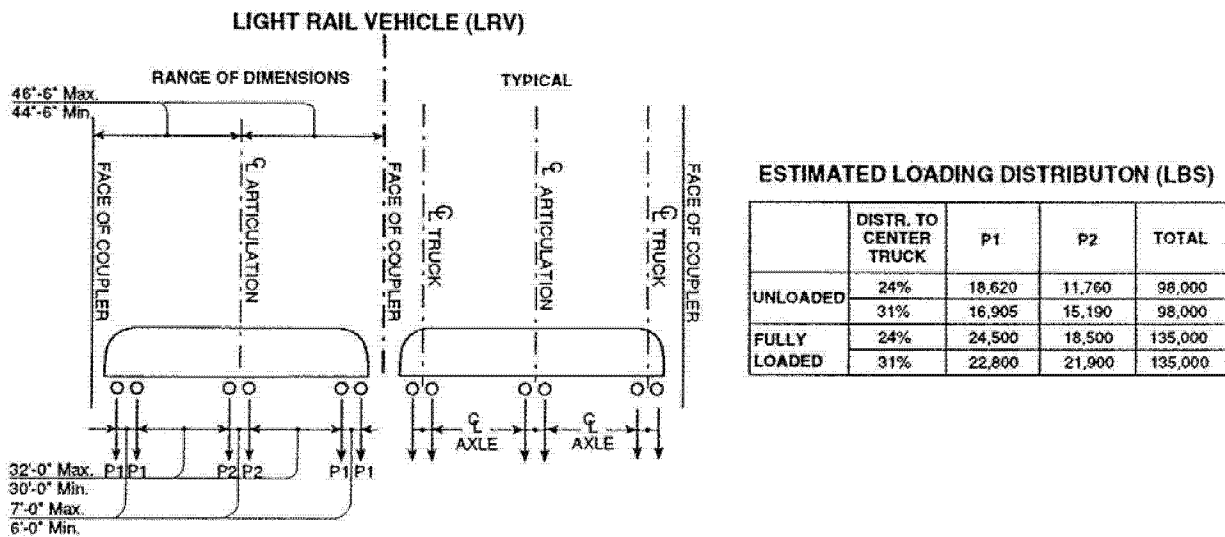


Figure 2-3: LRT Loading Distribution

The fully loaded 135,000 pound weight of the vehicle is distributed over a bogie (undercarriage truck) span of about 30 feet. The total vehicle coupler distance is about 90 feet.

An articulated vehicle distributes its load more uniformly along the guideway length, tends to conform to the horizontal curvature of the guideway better than one that is not articulated. This reduces the length of its criteria's dynamic envelope and allows the tracks to be spaced more closely together. This has benefits for the guideway girders and piers, especially one supporting two trackways.

The use of continuous steel running rails produces several beneficial guideway structural characteristics. The rails are supported above the guideway girders by concrete plinths normally about 6 inches high. This removes most of the criteria alignment tolerance problems for vertical and horizontal curvature and super-elevation, as well as those caused by concrete creep, shrinkage, short term change in camber, and differential settlement of the foundations. Most of these benefits are not available to BRT roadways, monorails, or maglevs.

The greatest cost advantage of steel running rails supporting steel wheels is the experience and simplicity that has been developed for switching and other special trackwork. For a single girder supporting two trackways, the change in structural load resulting from a crossover is a minor variation in vehicle live load.

Several criteria problems do exist for steel rail systems. Passenger comfort requires continuous steel running rail. But this continuity applies temperature change forces to the guideway structure girders and piers that can become serious, especially on curved sections. This force can also lead to a broken rail if not properly installed to the specified criteria.

An additional criteria concern is the potential derailment of a train. It is possible to install guard rails or restraining rails for this problem. Guard rails limit the lateral

movement of the train after a derailment, while restraining rails resist the tendency to derail. Owners vary in the usage of these two solutions but most use restraining rails only on sharp curves with no further precautions on more tangent sections. Derailment is therefore one of the criteria design loads for most steel rail systems. This somewhat difficult force concept is shown in Figure 2-4.

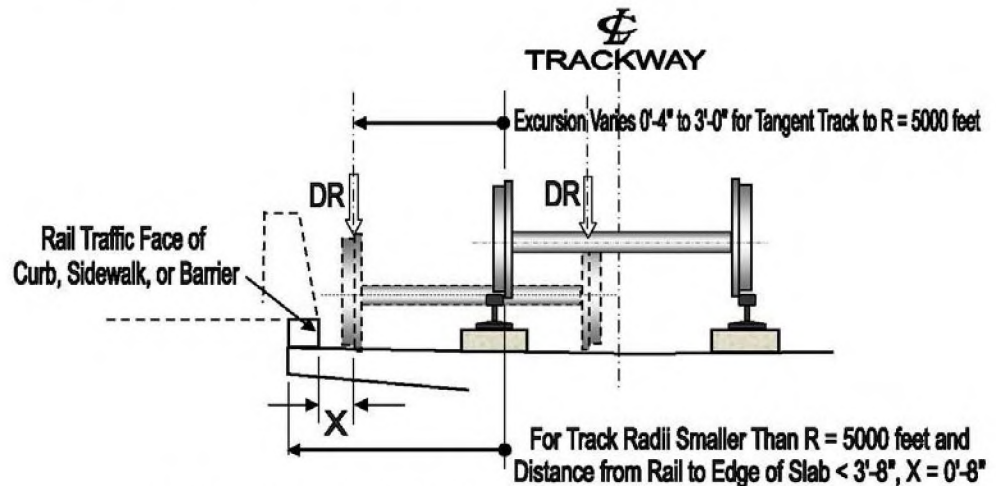


Figure 2-4: Lateral Vehicle Excursion for Vertical DR Load

Guideway girder dynamics enter into the criteria for all moderately high speed transit systems being considered for the Honolulu High-Capacity Transit Corridor with the exception of BRT. For LRT and HRT, this is mainly a vertical ride comfort criteria that requires the girder to have a period of vibration that will not result in harmonic resonance with the vehicle undercarriage. Due to the usual width of steel rail guideway girders, torsional resonance is not assumed to occur.

During a seismic event, at least one train is assumed to occupy the guideway for either dual or single track guideways. This is because all steel rail, monorails, and maglevs have lateral restraining devices that transmit the seismic force from the vehicle to the guideway. This is not a requirement for a BRT system.

This chapter covers the second of four technology options being evaluated for use on the Fixed Guideway Alternative. The functional, operational, and physical characteristics of the RRT vehicle and its associated typical design criteria are based on comparable RRT Project facilities recently entering revenue service.

Vehicle Characteristics

The RRT vehicles to be operated on the fixed guideway facilities will be stainless steel, rigid body type, utilizing four axle cars in a married pair configuration. A married pair (car “A” and car “B” coupled together) enables bidirectional travel. The RRT facilities will be designed to accommodate a maximum train of 3 married pairs (six cars). Loading and unloading of passengers will be from a full height passenger platform.

Traction power pick-up is via paddles mounted on the vehicle below floor height. Traction power is distributed by means of a third rail.

In addition to the train operator, the cars are normally operated from an Operational Control Center (OCC) through a modern Automatic Train Control system to enhance operations and increase the safety of the passengers.

RRT vehicles will be designed for passenger comfort with comfortable seating, air conditioning, and adequate interior lighting suitable for reading comfort and safety.

Basic Dimensions

- Car length: 75 feet 5 inches
- Car width: 10 feet 6 inches
- Car height: 12 feet 5 inches
- Floor height: 43.3 inches
- Weight, max: 110,630 lbs (fully loaded)

Vehicle Performance

- Maximum operating speed: 80 mph
- Line voltage: 750 V dc
- Maximum acceleration: 3 mph per second
- Braking distance: 1,170 ft from 80 mph

Alignment Design

Alignment design will be based on vehicle clearances and utilize horizontal and vertical curves established to ensure comfort, safety, and operational efficiency.

Guideway Widths

- Typical section at grade tangent track: see Figure 3-1
- Typical section aerial: see Figure 3-2

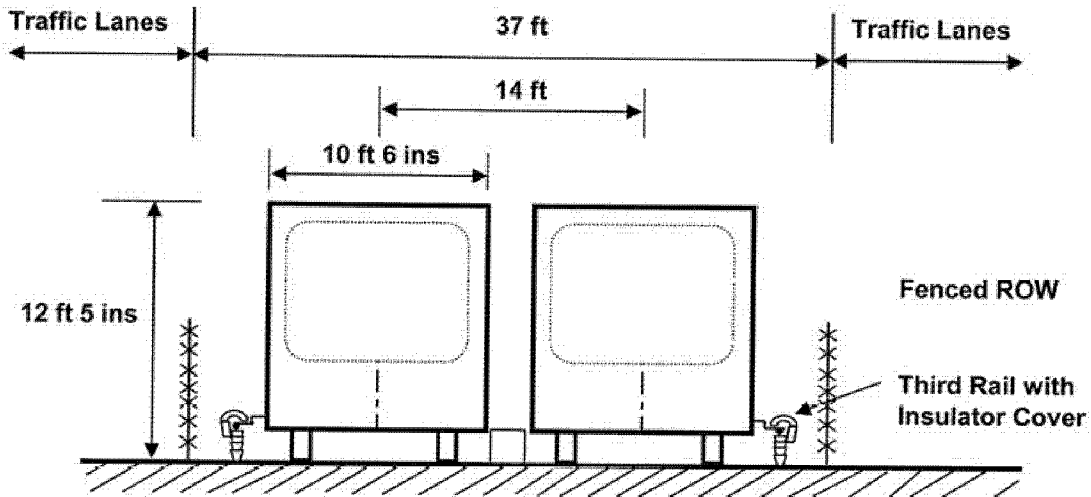


Figure 3-1: RRT At-Grade Guideway

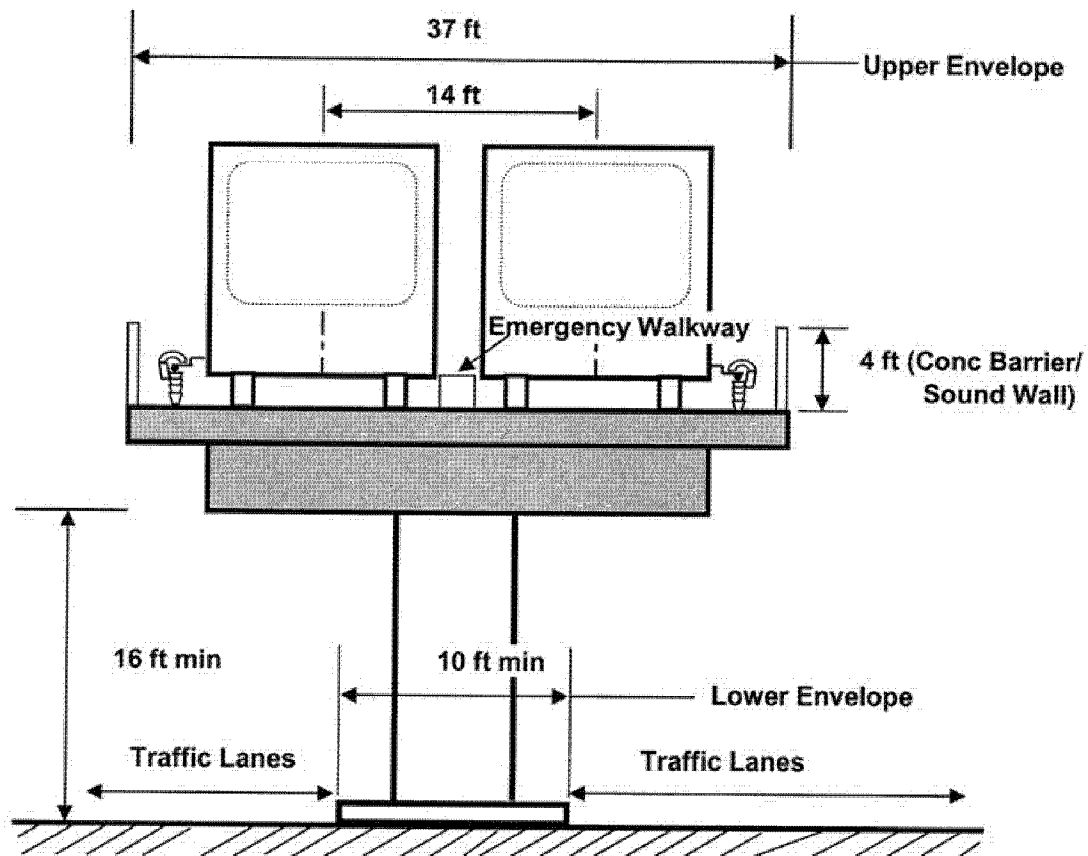


Figure 3-2: RRT Elevated Guideway

Horizontal Alignment and Superelevation

The parameters for the design of horizontal alignments are similar as for the LRT option, except that where practical, the geometrics shall accommodate the maximum operating speed of 80 mph.

Track Spacing

Track spacing will vary, depending on the type of construction used for the particular section. Minimum center-to-center track dimensions for open route parallel tracks shall be 14 feet absolute minimum, 15 feet preferred. Increased center-to-center track dimensions will be required through curved sections. Center-to-center track dimensions for parallel tracks in center platform station will be dependant upon the platform width.

Superelevation

In the design of horizontal alignments, the allowable speed throughout the curved sections shall be determined by passenger comfort as related to superelevation. Superelevation is defined as the difference in inches between high rail and low rail.

Curve Radii

- Mainline track: 1,000 foot minimum
- Secondary track: 1,000 foot minimum
- Yard track: 500 foot minimum

Vertical Alignment

The vertical profile shall represent the elevation of the top of the low rail.

Grades

The maximum sustained grade for mainline tracks shall be 3.0 percent; the absolute maximum sustained grade shall be 4.0 percent. For distances not greater than 1,650 feet, an absolute maximum grade of 6.0 percent may be used. A minimum vertical tangent length of 100 feet is required.

Vertical Curvature

- All changes in grade shall be connected by parabolic vertical curves.
- Minimum vertical curve:
 - Crest = $G1 - G2 \cdot V \cdot V / 25$ feet
 - Sag = $G1 - G2 \cdot V \cdot V / 45$ feet
- Maximum gradient: 6.0%

Clearance Requirements

Clearance Envelope

The clearance envelope is defined as the space occupied by the dynamic outline of the RRT vehicle plus an additional running clearance of 2 inches around the dynamic outline.

Horizontal Clearances

Minimum horizontal clearances measured from the centerline of track shall be as follows:

- Adjacent parallel tracks: 14 foot centers
- Retaining walls or continuous restrictions: 9 feet with provision made for safety walk, 6 feet 6 inches with no provision made for safety walk
- Fences parallel to track: 11 feet 6 inches
- Wall of cut-and-cover structure in subway: 8 feet 3 inches on side of safety walk, 6 feet 6 inches on side without safety walk

Vertical Clearances

Minimum vertical clearances, measured from top of high rail shall be as follows:

- Fixed structure in subway, cut-and-cover section: 14 feet
- Fixed structure in open: 14 feet

Trackwork

The design criteria for RRT trackwork are the same as for LRT trackwork. However, modifications may be necessary to accommodate designs unique only to most RRT, such as the third rail power requirements.

Station Design

The general design criteria for RRT stations are the same as for LRT stations. However, the platform loading type and size differs slightly.

Platform Configuration

All station platforms shall be high level loading type, either center platform or side platform.

Platform Size

Station platforms shall be sized to accommodate site specific patronage projections. For platform sizing and means of egress, including emergency conditions, refer to NFPA 101 and NFPA 130.

- Platform widths-unless otherwise specified:
 - Center platform: 28 feet

- Side platform: 14 feet
- Platform lengths:
 - 2 married pairs: 310 feet
 - 3 married pairs: 460 feet

Structural Design

Recent heavy rail systems in the US all employ a third rail at the track level for power electrification. This is an aesthetic benefit over the use of a pantograph that requires an overhead catenary. The axle loads and bogie spacing for a major HRT system in current use is shown in Figure 3-3.

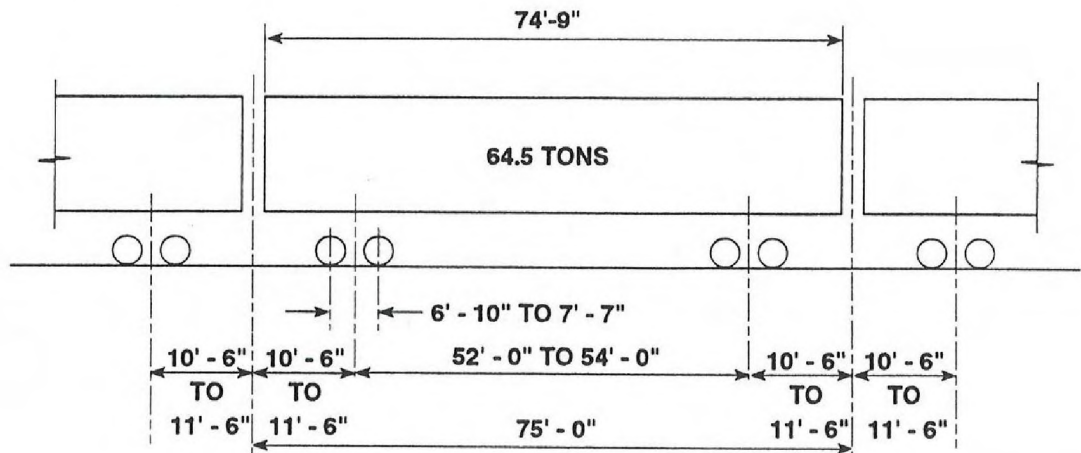


Figure 3-3: RRT Size and Loading

Design loads for RRT are as follows:

- Vehicle: 82,000 pounds
- Passengers: 47,000 pounds
- Total: 129,000 pounds

The fully loaded vehicle weight of 129,000 pounds is distributed over a bogie span of about 53 feet. The total vehicle coupler distance is about 75 feet. This is about 15 percent more weight per foot than the previous light rail vehicle, but there are also light rail vehicles of comparable weight per foot. The real difference occurs between the two types of vehicle when the heavy bogies for two LRT or two HRT vehicles are connected so their bogies are at their shortest distance apart. This is about 20 feet in both cases and the heavy rail vehicle applied force is about 30 percent more than that of the light weight vehicle.

Due to the 53 feet between the HRT bogies, the dynamic envelop for both horizontal and vertical clearances on horizontal curves, vertical changes in grade, and trackway superelevation are greater than for an LRT. Derailment criteria forces are now somewhat

greater due to the increased axle loads. The same continuous rail plinth and girder design benefits and concerns that accompanied the LRT structure also affect the HRT structure.

This chapter covers the third of four technology options being evaluated for use on the Fixed Guideway Alternative. The functional, operational and physical characteristics of the monorail vehicle and its associated typical design criteria are based on data recently published for monorail Systems currently under development or in service. Other monorail technologies may also be available.

Vehicle Characteristics

The vehicle is a straddle type that rides on the top of a dedicated guide beam structure approximately two to three feet wide. A rubber-tired carriage contacts the beam on the top and both sides for traction and to stabilize the vehicle.

The vehicles are powered by electric motors fed by dual third rails, contact wires or electrified channels attached to or enclosed in their guide beams.

Types of cars available are end cars with operator cabs (for manual operation) and middle cars. The number of middle cars can be varied to suite operation requirements.

Loading and unloading of passengers will be from an elevated passenger platform.

Basic Dimensions

A 4 car modular train set is approximately 138 feet long, 11 feet high, and 9 feet wide.

Vehicle Performance

- Maximum operating speed: 50 mph
- Cars can be operated manually or driverless utilizing Automatic Train Control (ATC) technology

Alignment Design

Alignment design will be based on vehicle clearances and utilize horizontal and vertical curves established to ensure comfort, safety and operational efficiency.

Monorail technology utilizes moving beam switch technology, for moving between guideways that is significantly more complex and expensive compared to normal simple rail crossovers.

Guideway Widths

- Typical section at grade tangent track: see Figure 4-1
- Typical section aerial: see Figure 4-2

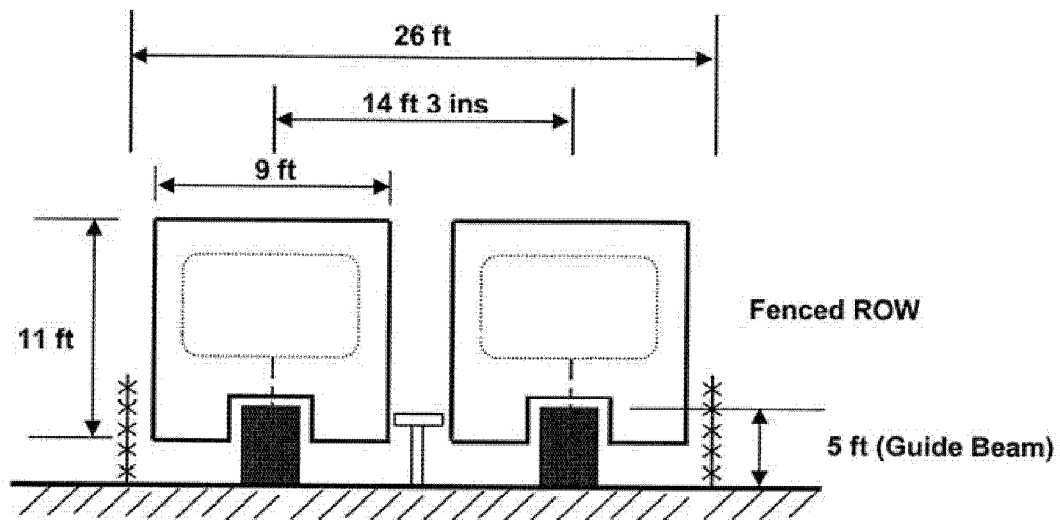


Figure 4-1: Monorail At-Grade Guideway

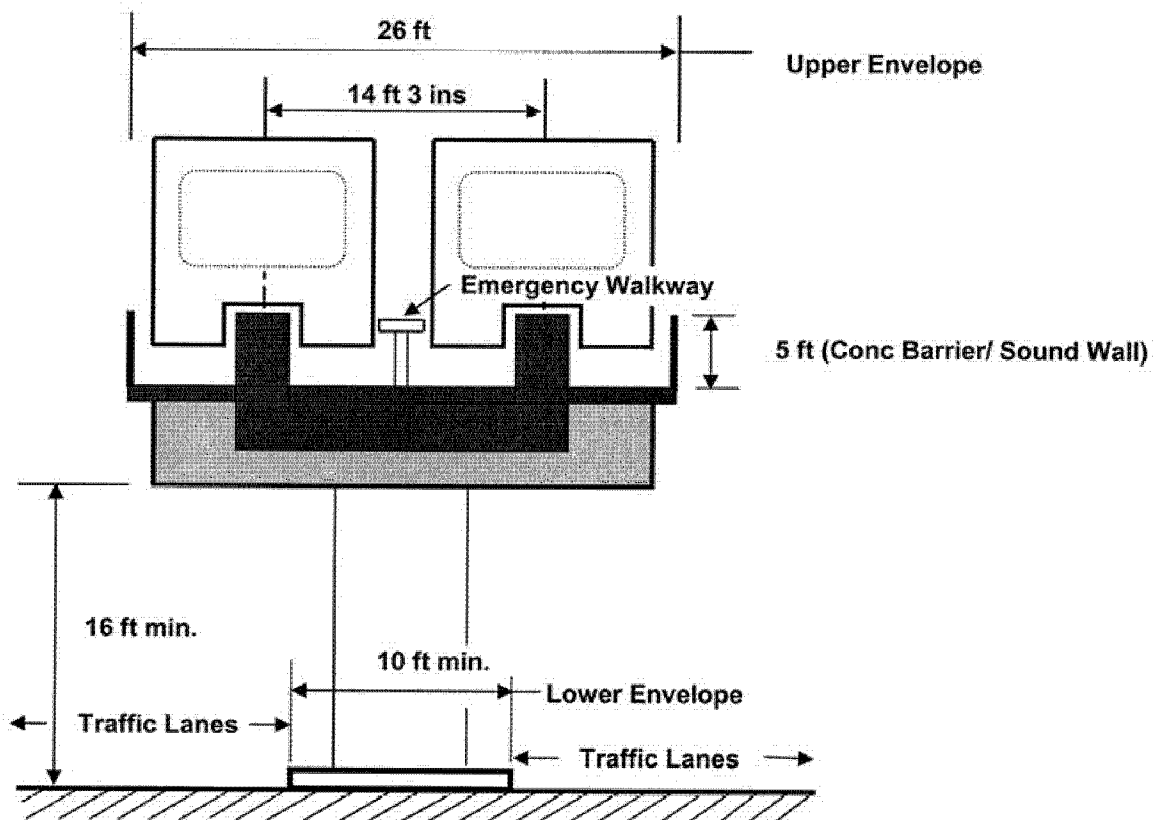


Figure 4-2: Monorail Elevated Guideway

Horizontal Alignment and Superelevation

Geometry of the train set configurations necessitate the minimum horizontal turning radius be at least 120 feet and ideally should be greater than 200 feet.

The superstructure for the monorail typically consists of haunched pre-cast concrete guideway beams made continuous in five-span frames by post-tensioning. The spans range from 65 to 120 feet. The guideway beams are supported on cast-in-place post-tensioned concrete bent caps, which are supported by cast-in-place concrete columns founded on cast-in-drilled-hole pile shafts.

The monorail requires an exclusive guideway that cannot be crossed by either foot or public vehicular traffic, due to the 5 foot high exposed guide beam. The monorail profile must therefore go below or above grade in these locations.

The horizontal alignment of mainline tracks shall consist of tangents joined to circular curves by spiral transition curves. Spiral curves need not be used in yard and service areas.

Track Spacing

Track spacing will vary, depending on the type of construction used for the particular section. Minimum center-to-center track dimensions for open route parallel tracks shall be 14 feet 3 inches at 50 mph. Increased center-to-center track dimensions will be required through curved sections. Center-to-center track dimensions for parallel tracks in station areas will be dependant upon the width of station center platform.

Superelevation and Curvature

Curvature and superelevation shall be set to maximize design speed, which shall be set to equal or exceed the operating speed. Consideration should be given to the acceleration and deceleration characteristics of the monorail vehicle. When ever practical, the geometrics shall accommodate the maximum operating speed of 50 mph. Where the location of curves, station stop spacing, construction limitations, and the performance characteristics of the design monorail vehicle require the operating speed to be less than the maximum, the track geometrics shall suit the reduced speed.

In the design of horizontal alignments, the allowable speed throughout the curved sections shall be determined by passenger comfort as related to superelevation.

- Maximum superelevation: 12 degrees, (16 degrees in special cases).
- Curve Radii: 1,150 ft minimum

Vertical Alignment

The vertical profile shall represent the elevation of the top of the low side of the track.

Grades

The maximum sustained grade for mainline tracks shall be 10.0 percent.

Vertical Curvature

All changes in grade shall be connected by parabolic vertical curves.

Clearance Requirements

Clearance Envelope

The clearance envelope is defined as the space occupied by the dynamic outline of the design of the monorail vehicle plus an additional running clearance of “X” inches around the dynamic outline. “X” would be developed in conjunction with vehicle manufacturer and operating speed.

Horizontal Clearances

Minimum horizontal clearances measured from the centerline of track shall be as follows:

- Adjacent parallel tracks: 14 feet 3 inch centers
- Fences parallel to track: 7 feet 3 inches
- Wall of cut-and-cover structure in subway: 8 feet 3 inches on side of safety walk

Vertical Clearances

Minimum vertical clearances, measured from top of high rail shall be as follows:

- Fixed structure in subway, cut-and-cover section: 17 feet
- Fixed structure in open: 17 feet

Station Design

The general design criteria for monorail stations are the same as for LRT stations. However, the platform size may vary.

Platform Configuration

All station platforms shall be low level loading type, either center platform or side platform.

If a driverless system is used all stations must be equipped with platform sliding barrier doors that prevent unauthorized access to the guideway, or vehicles, from the station platform.

Platform Size

Station platforms shall be sized to accommodate site specific patronage projections. For platform sizing and means of egress, including emergency conditions, refer to NFPA 101 and NFPA 130.

- Platform widths, unless otherwise specified:
 - Center platform: 18 feet
 - Side platform: 14 feet
- Platform lengths for a consist of:
 - One 4 car modular train set: 145 feet

- Two 4 car modular train sets: 295 feet

Structural Design

Structures for monorail vehicles normally have shorter spans of the order of 80 to 100 feet due to the precision required for the guideways for the horizontal and vertical rubber tired running surface incorporated directly into the concrete girder. This precision must be controlled by the criteria for the entire guideway installation process. In addition the span must be short enough to maintain lateral stability against compression in the top flange and torsional stability on curves. These problems arise due to the narrow width of the beam required to allow the vehicle to straddle the beam. Additional rigorous criteria tolerance controls place limits on pre-casting, pre-stressing or post-tensioning, and concrete camber allowances, creep and shrinkage.

A steel guideway eliminates some of the problems, but this has not been used by any recent transit level operating systems. Another consideration is the service life of the concrete running surface. It is not likely to last 75 years under transit level usage. The criteria should therefore consider the operational disruption caused by maintenance, repair, and possible replacement.

The 100-foot normal span limitation can lead to costly special structures where longer spans are essential due to site restrictions. Unless otherwise demonstrated with a complete set of material and installation criteria, it should be assumed that the cost of the guideway structure needed to support a monorail vehicle is comparable to steel rail systems. This is born out by the Hitachi Series 1000 monorail is pictured in Figure 4-3.

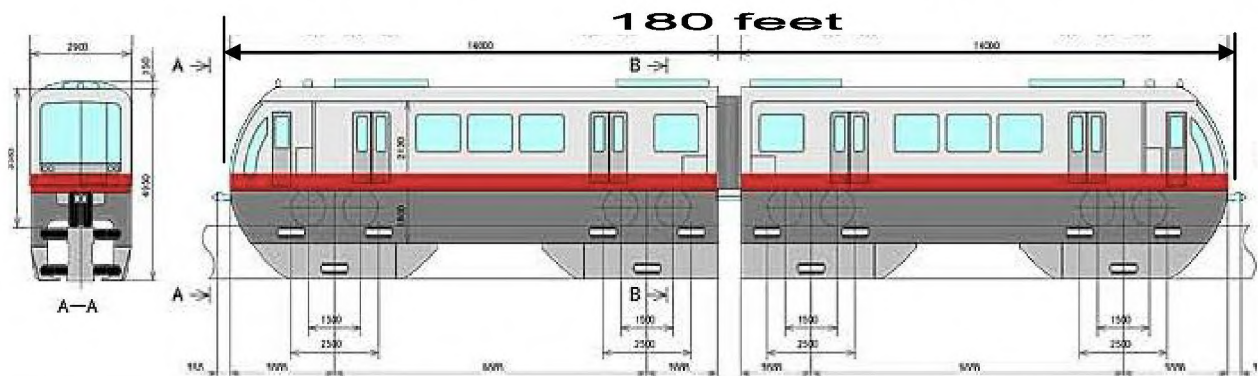


Figure 4-3: Monorail Vehicle

Each of the vehicle cars has a total length of 90 feet and a total axle load of 25,000 pounds spaced at about 30 feet. Therefore in most respects, the guideway requirements for live loads are the same as for an LRT. One advantage for monorail over steel rail is that there are no derailment concerns for a monorail.

This chapter covers the last of four technology options being evaluated for use on the Fixed Guideway Alternative. The functional, operational, and physical characteristics of the Maglev and its associated typical design criteria are based on data recently published for a Maglev Transrapid System currently under development. Other technologies may be available.

Vehicle Characteristics

The Maglev vehicles to be operated on the fixed guideway facilities will be a non-contact; electromagnetic levitation and guidance; attractive principle; 3/8 inch gap (nominal); system. Propulsion is achieved by means of a synchronous longstator linear motor mounted on the guideway.

The Maglev vehicle can be configured in a two-end section consist and can be supplemented by the addition of middle sections, up to eight middle sections maximum.

The Operational Control System is a fully automated communication and control system, digital radio, driver optional, technology.

Loading and unloading of passengers will be from an elevated passenger platform.

The Maglev vehicles will be designed for passenger comfort with comfortable seating, air conditioning, and adequate interior lighting suitable for reading comfort and safety.

Basic Dimensions

- Car length end section: 88 feet 6 inches
- Car width end section: 12 feet 2 inches
- Car height end section: 13 feet 7 inches
- Car length middle section: 81 feet 4 inches
- Car width middle section: 12 feet 2 inches
- Car height middle section: 13 feet 7 inches
- Number of seats end section: 62 to 92
- Number of seats middle section: 84 to 126

Capacity

Number of Sections	2	4	6	8	10
Passenger Seats (high density)	184	436	688	940	1192
Passenger Seats (low density)	124	292	460	628	796

Vehicle Performance

- Design speed: 340 mph

- Maximum operating speed rural: 310 mph
- Maximum operating speed urban: 155 mph
- Acceleration: 4.9 ft/s squared

Performance

Acceleration Performance	Time (seconds)	Distance (feet)
0-60 mph	31	1,391
0-125 mph	61	5,577
0-185 mph	97	13,780
0-250 mph	148	29,856
0-310 mph	256	74,475
Braking Performance	Time (seconds)	Distance (feet)
60-0 mph	30	1,362
125-0 mph	59	5,171
185-0 mph	88	12,815
250-0 mph	117	22,064
500-0 mph	147	33,367
Example Trip Times		
Airport Connector (25 Miles): 10 min. (no intermediate stop)		
City Connector (185 Miles): 53 min. (one 2 min. intermediate stop)		
Long Distance (500 Miles): 115 min. (two 2 min. intermediate stops)		

Data depends on propulsion layout

Alignment Design

Alignment design will be based on vehicle clearances and utilize horizontal and vertical curves established to ensure comfort, safety and operational efficiency.

The single- or double-track guideway of the Maglev system consists of individual guideway beams made of steel or concrete in standard lengths. The guideway can be installed at-grade or elevated depending on the alignment needs.

An elevated guideway is especially appropriate in areas that should not be separated for ecological or agricultural reasons and/or where existing traffic routes should not be blocked by the new line. Variable column heights and standard beam spans allow flexible adaptation of the guideway to the topography. Elevated guideways are mounted on discrete foundations with columns architecturally suited to the surrounding infrastructure.

The guideway is installed at-grade mainly where it can be co-located with existing traffic routes (roads, railroads) as well as in tunnels and on primary civil structures such as bridges and stations. At-grade guideways are mounted on continuous foundations and are typically fenced-in to improve safety.

Guideway Widths

- Typical Section Guideway: see Figure 5-1

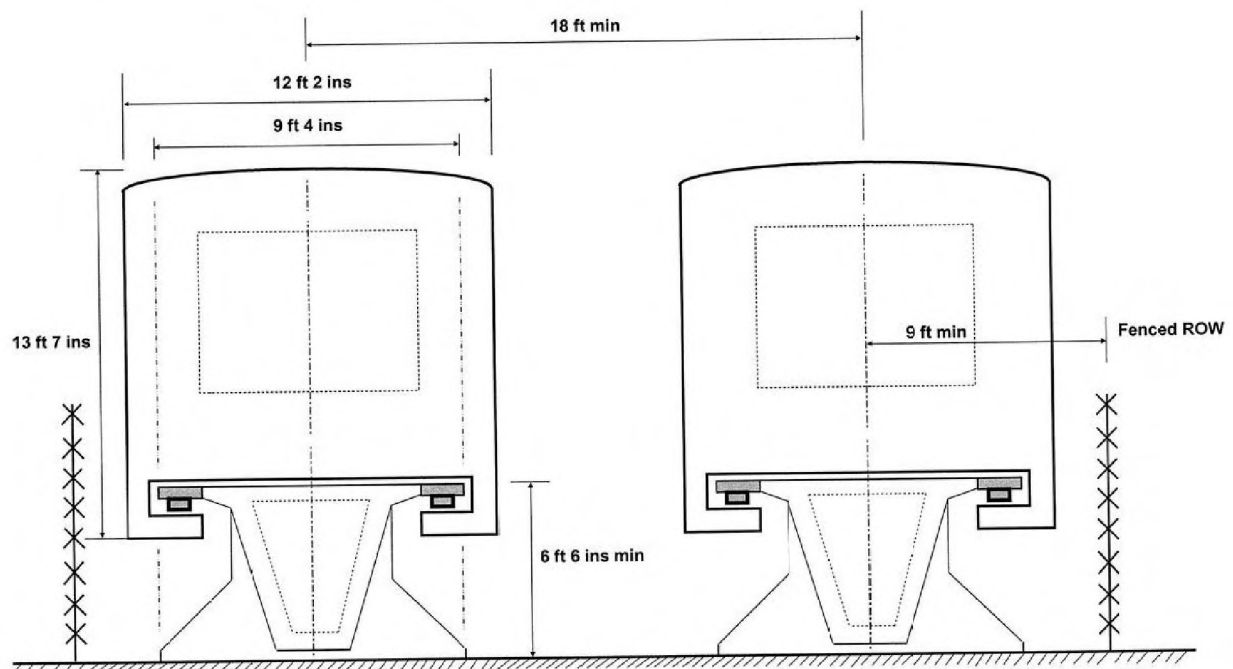


Figure 5-1: Maglev Guideway

Horizontal Alignment and Superelevation

The horizontal alignment of mainline tracks shall consist of tangents joined to circular curves by spiral transition curves. Spiral curves need not be used in yard and service areas.

Curvature and superelevation shall be set to maximize design speed, which shall be set to equal or exceed the operating speed. Consideration should be given to the acceleration and deceleration characteristics of the Maglev vehicle. When ever practical, the geometrics shall accommodate the maximum operating speed of 310 mph for rural environments or 155 mph for urban environments. Where the location of curves, station stop spacing, construction limitations and the performance characteristics of the design Maglev vehicle require the operating speed to be less than the maximum, the track geometrics shall suit the reduced speed.

Track Spacing

Track spacing will vary, depending on the type of construction used for the particular section. Minimum center-to-center track dimensions for open route parallel tracks shall be 18 feet at 310 mph. Increased center-to-center track dimensions will be required through curved sections. Center-to-center track dimensions for parallel tracks in station areas will be dependant upon the width of station center platform.

Track Switches

Bending beam switch with electromechanical setting drives are typically 246 feet long for 60 mph and 495 feet long for 124 mph.

Superelevation

In the design of horizontal alignments, the allowable speed throughout the curved sections shall be determined by passenger comfort as related to superelevation. Maximum superelevation is typically 12 degrees (16 degrees in special cases).

Curve Radii

Design Criteria	Radius (feet)
Minimum	1,150
125 mph	2,315
185 mph	5,215
250 mph	9,270
310 mph	14,485

Vertical Alignment

The vertical profile shall represent the elevation of the top of the low side of the track.

Grades

The maximum sustained grade for mainline tracks shall be 10.0 percent.

Vertical Curvature

All changes in grade shall be connected by parabolic vertical curves.

Clearance Requirements

Clearance Envelope

The clearance envelope is defined as the space occupied by the dynamic outline of the design of the Maglev vehicle plus an additional running clearance of “X” inches around the dynamic outline. “X” would be developed in conjunction with vehicle manufacturer and operating speed.

Horizontal Clearances

Minimum horizontal clearances measured from the centerline of the adjacent parallel tracks shall be 18 feet centers at 310 mph.

Vertical Clearances

Minimum vertical clearances, measured from top of high rail shall be as follows:

- Fixed structure in subway, cut-and-cover section: 22 feet
- Fixed structure in open: 22 feet

Station Design

The general design criteria for Maglev stations are the same as for LRT stations. However, the platform loading type and size may vary.

Platform Configuration

All station platforms shall be high level loading type, either center platform or side platform.

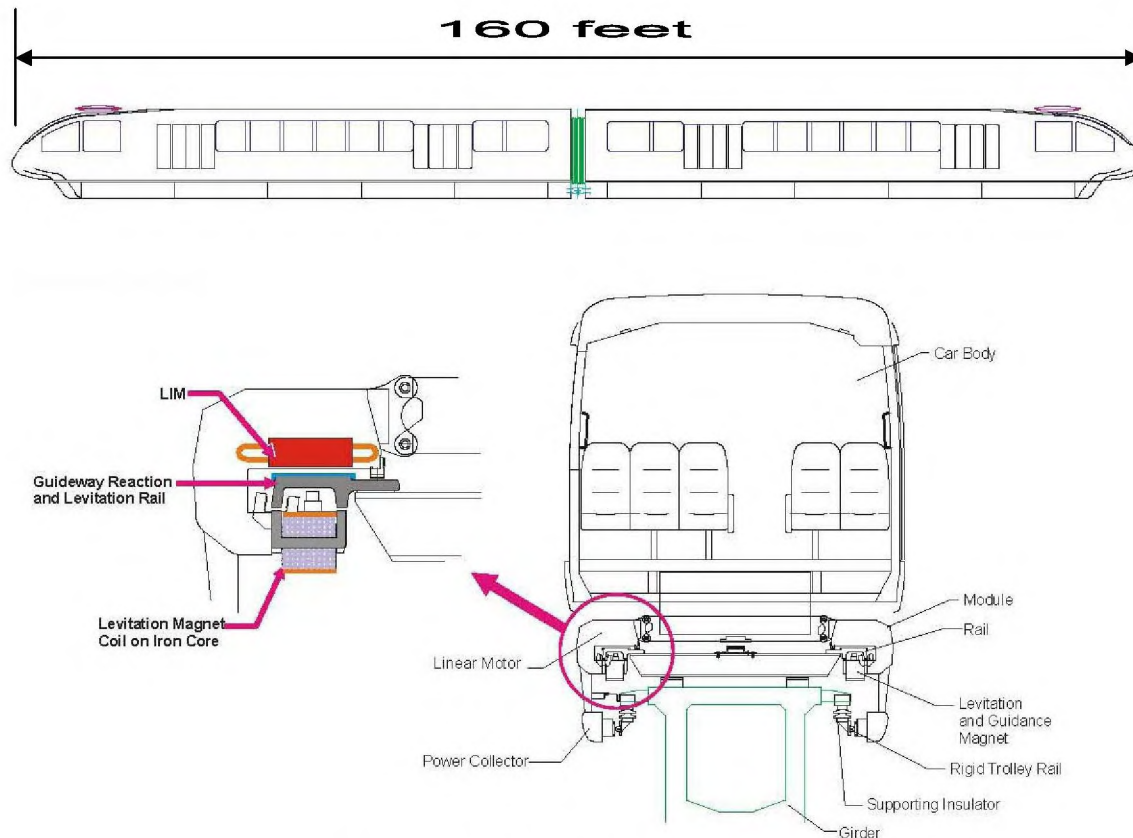
Platform Size

Station platforms shall be sized to accommodate site specific patronage projections. For platform sizing and means of egress, including emergency conditions, refer to NFPA 101 and NFPA 130.

- Platform widths, unless otherwise specified:
 - Center platform: 27 feet 10 inches
 - Side platform: 12 feet
- Platform lengths: to be coordinated with the agreed maximum train size

Structural Design

The guideway structures supporting maglev vehicles have most of the same tolerance problems of monorail with the additional problem associated with the precise installation of the propulsion/levitation module. The vehicle system shown in Figure 5-2 is the Japanese Chubu CHSST system that has successfully carried over 3 million passengers since the mid 1970's.



Close-up of propulsion/levitation module for LIM.

Figure 5-2: Maglev Vehicle and Propulsion/Levitation Module

Each of the two cars is 80 feet long and with only seated passengers weighs 97,000 pounds. Configured for full passenger transit loading, the vehicle weight per foot will be comparable to other rail systems.

The vehicle live load force on the guideway is more uniform than for any other system due to the distribution of the levitation modules. This is nevertheless offset by the rigorously limited deflection criteria allowed for the guideway that is nearly twice that needed for any other system.

Like monorail, there is little concern for derailment for most maglev systems.

Chapter 6

Geometric Design Criteria for Fixed Guideway Conceptual Design

The fixed guideway design criteria selected for conceptual design were selected from appropriate characteristics from the four technology options. Criteria also take into consideration the sensitive constraints within the Honolulu corridor environment. The conceptual design shown on plans, profiles, and layouts of station and guideway structures, generated using these design criteria, were then used as a basis for evaluating environmental impacts and estimating capital costs that supported the AA.

The following sections summarize the geometric design criteria and design features of the Fixed Guideway Alternative presented in the AA. The use of design criteria specific to certain technologies does not indicate a preference for that technology and does not preclude the selection of a different technology in the future.

Vehicle Characteristics

Design vehicle would be a Standard Low Floor vehicle that permits level boarding of passengers from a platform directly into the vehicle with the following characteristics:

- Length of vehicle to be: 90.0 to 94.0 feet over couplers
- Maximum width: 8 feet 9.5 inches over car body, 8 feet 11.7 inches over door threshold
- Maximum height: 12.0 feet 8.0 inches (third rail power peddle or pantograph power collector in down position)
- Vertical clearance required: 13 feet minimum (third rail power or pantograph power collector in down position) to 23 feet maximum (if pantograph power collector used)
- Door threshold: 14 inches above top-of-rail
- Weight, max: 97,500 lb (fully loaded)

Vehicle Performance

- Maximum operating speed: 65 mph
- Acceleration: 3 mph per second
- Deceleration: 2.7 mph per second

Traction Power System Characteristics

The Overhead Contact System (OCS) would utilize three possible configurations: standard depth catenary, low profile catenary, and single contact wire. The OCS for all types would be supported by bracket arms or span guys attached to poles located either outside or between the tracks. The nominal OCS voltage will be 750 V dc.

Basic Dimensions

- Contact wire height above top-of-rail:
 - 15 feet normal for fully exclusive ROW
 - 14 feet minimum for fully exclusive ROW
 - 18 feet minimum for mixed traffic
 - 23 feet at grade crossings
- Clearance center line of track to center of OCS pole:
 - Tangent track: 7 feet 6 inches minimum
 - Tangent track 7 feet absolute minimum
 - Clearances for horizontal curves are greater

Alignment Design

Guideway Widths

- Typical section at grade tangent track: see Figure 6-1
- Typical section aerial: see Figure 6-2

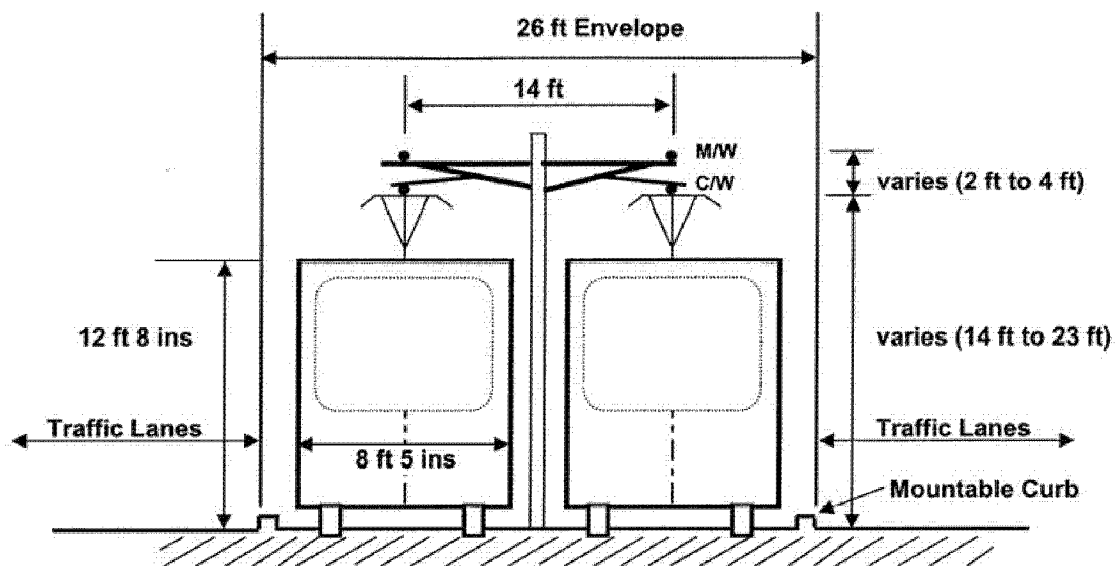


Figure 6-1: Conceptual Design At-Grade Guideway

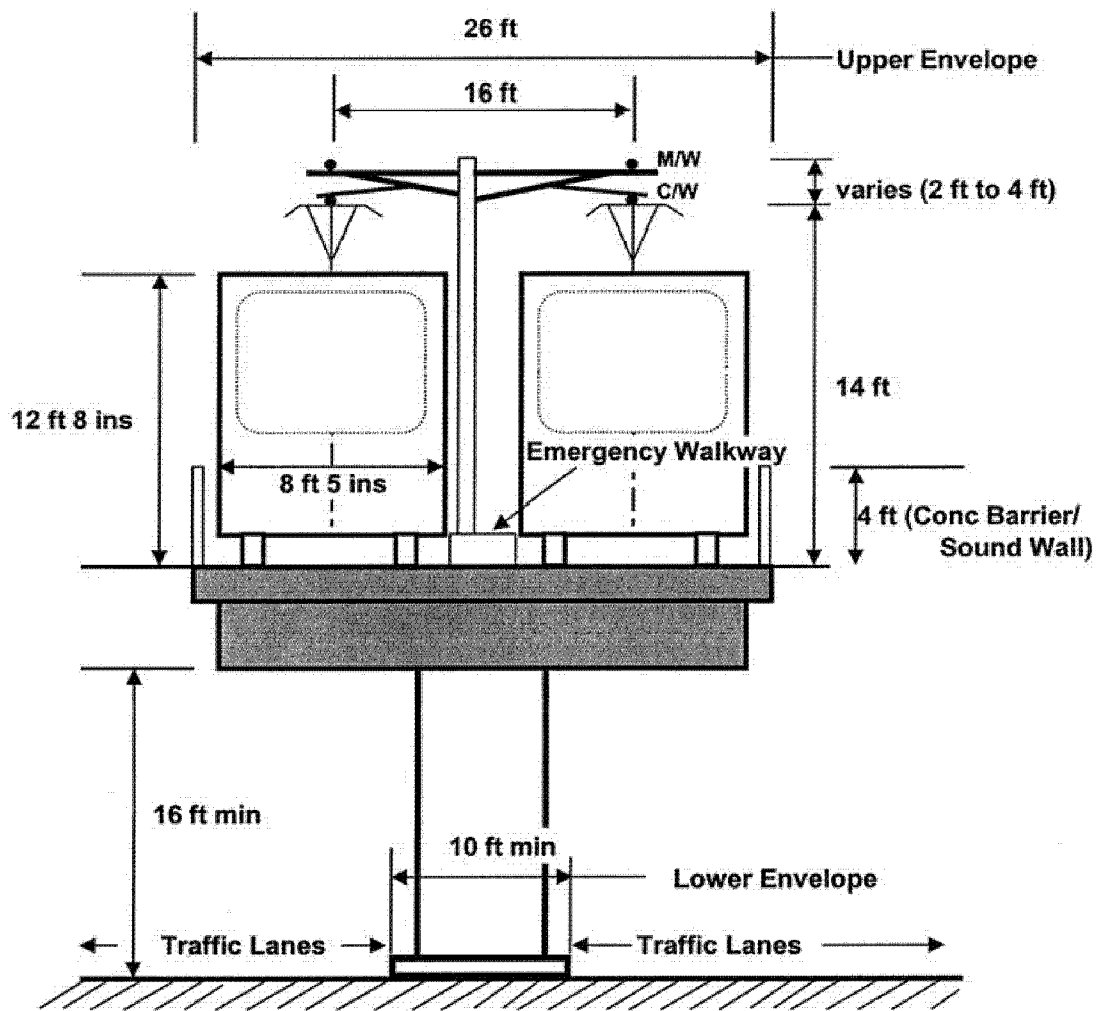


Figure 6-2: Conceptual Design Elevated Guideway

Horizontal Alignment and Superelevation

The parameters for the design of horizontal alignments shall be in accordance with the recommendations of the most current version of the Manual for Railway Engineering, published by the American Railway Engineering and Maintenance-of-Way Association (AREMA) except as modified herein.

The horizontal alignment of mainline tracks shall consist of tangents joined to circular curves by spiral transition curves. Spiral curves need not be used in yard and service areas. The desirable minimum tangent length between curved sections shall be 200 feet. The minimum length shall be 100 feet, or three times the design speed, whichever is greater.

Curvature and superelevation shall be set to maximize design speed, which shall be set to equal or exceed the operating speed. When ever practical, the geometrics shall accommodate the maximum operating speed of 65 mph. Where the location of curves,

station stop spacing, and construction limitations require the operating speed to be less than the maximum, the track geometrics shall suit the reduced speed.

Track Spacing

Track spacing will vary, depending on the type of construction used for the particular section. Minimum center-to-center track dimensions for open route parallel tracks shall be 15 feet. Increased center-to-center track dimensions will be required through curved sections. Center-to-center track dimensions for parallel tracks in station areas having center platforms will be dependant upon the width of the platform.

Superelevation

In the design of horizontal alignments, the allowable speed throughout the curved sections shall be determined by passenger comfort as related to superelevation. Superelevation is defined as the difference in inches between high rail and low rail.

Horizontal Curve Radius

The minimum curve radii (R) shall be as follows:

- R = 1,200 feet desirable minimum for all sections
- R = 500 feet minimum on aerial structures
- R = 300 feet minimum for at-grade sections
- R = 450 feet minimum for underground structures constructed by tunnel boring machines
- R = 250 feet minimum for underground structures constructed by cut and cover methods

The following table summarizes the locations along the First Project/Minimum Operable Segment (MOS) that have less than the desirable minimum curve radii:

Station at Beginning of Curve	Radii in feet	Comment
732+87	800	Designed for reduced speed, with end of curve approximately 100 feet from edge of station platform.
1060+45	600	Follows roadway right-of-way. Options for providing larger radii curve to be evaluated during PE.
1150+00	800	Avoids building. Options for providing larger radii curve to be evaluated during PE.
1307+33	1,000	Designed for reduced speed, with end of curve approximately 100 feet from edge of station platform.
1316+78	800	Designed for reduced speed, with end of curve approximately 100 feet from edge of station platform.
1358+19	800	Designed for reduced speed, with end of curve approximately 100 feet from edge of station platform.

1372+90	250	Designed for reduced speed, with end of curve approximately 100 feet from edge of station platform. Options for providing larger radii curve to be evaluated during PE.
1430+97	700	Designed for reduced speed, with end of curve approximately 100 feet from edge of station platform.
1441+01	400	Follows roadway right-of-way. Options for providing larger radii curve to be evaluated during PE.
1450+06	700	Aligned to minimize high-of-way and utility relocation impacts. Options for providing larger radii curve to be evaluated during PE.

During the preliminary engineering phase of the project, the alignment would be optimized with automated operating simulation software. This process confirms the operating parameters, including vehicle speed and the power requirements. In this analysis, the vehicle speed at every significant instance within the alignment would be validated and the assumed characteristics such as curve radii used are confirmed. It is at this stage that any modifications to improve the alignment would be accomplished appropriately.

Vertical Alignment

The vertical profile shall represent the elevation of the top of the low rail or lowest track-top feature.

Grades

The maximum sustained grade for mainline tracks shall be 3.0 percent; the absolute maximum sustained grade shall be 4.0 percent. For distances not greater than 500 feet, an absolute maximum grade of 7.0 percent may be used.

A desirable minimum vertical tangent of 100 feet, or three times the design speed, whichever is greater, is required for mainline track. An absolute minimum of 40 feet is required for yard tracks.

Vertical Curvature

All changes in grade shall be connected by parabolic vertical curves. Minimum vertical curve shall be:

- Crest = $G1 - G2 * V * V / 25$ feet
- Sag = $G1 - G2 * V * V / 40$ feet

Clearance Requirements

Clearance Envelope

The clearance envelope is defined as the space occupied by the dynamic outline of the design of the design vehicle plus an additional running clearance of 2 inches around the dynamic outline.

Horizontal Clearances

Minimum horizontal clearances measured from the centerline of track shall be as follows:

- Adjacent parallel tracks: 14 foot centers, absolute minimum
- Retaining walls or continuous restrictions: 9 feet with provision made for safety walk; 6 feet 6 inches with no provision made for safety walk
- Fences parallel to track: 11 feet 6inches
- Wall of cut-and-cover structure in subway: 8 feet 3 inches on side of safety walk, 6 feet 6inches on side without safety walk

Vertical Clearances

Minimum vertical clearances, measured from top of high rail shall be as follows:

- Fixed structure in subway, cut-and-cover section, exclusive ROW: 16 feet
- Fixed structure in open, mixed traffic: 23 feet

Trackwork

“Trackwork”, as used in this section refers to standard trackwork and special trackwork including turnouts, crossovers, double crossovers, and track crossings.

Track materials and special trackwork shall be based generally upon the recommendations in the most current American Railway Engineering and Maintenance-of-Way Association (AREMA) Manuals for Engineering (Volumes I and II), the Portfolio Of Trackwork Plans and upon other generally accepted transit industry standards, practices and recommendations as appropriate to reflect the physical and operating characteristics of the system.

Track shall be designed to minimize levels of stray currents resulting from the use of the running rails as the negative return circuit for the traction current.

Track shall be designed to limit the noise and vibration transmission due to the passage of the transit vehicles.

Tracks shall be designed for the maximum degree of constructability and maintainability. Maximum accessibility should be provided to track components requiring frequent maintenance (i.e., special trackwork).

Track components design shall be standardized to the greatest possible extent to facilitate maintenance and minimize the inventory of materials.

Standard Type of Track Construction

There are two general classes of Tracks:

1. Mainline Tracks - Tracks that carry revenue passengers.

2. Yard and Secondary Tracks – Tracks that do not carry revenue passengers, such as tracks constructed for the purpose of storing, maintaining, or switching vehicles.

Trackwork for these two general classes of track may be further classified into five basic types of standard trackwork

1. Ballasted track
2. Direct-fixation track
3. Slab track
4. Shop track
5. Embedded track

Track Gauge

The standard track gauge shall be 4 feet 8-½ inches. Track gauge shall be measured perpendicular to the gauge sides of the heads of the rails at a distance of 5/8 inch below the tops of rails. Wider gauges shall be used in curves depending upon the degree of curvature.

Gauges for special trackwork shall be as recommended in AREA Portfolio of Trackwork Plans except as modified to reflect the physical and operational characteristics of the system.

Station Design

The station design shall comply with relevant accessibility standards including the American with Disabilities Act (ADA). The layout of the station should promote a “user friendly” atmosphere with ease of use and route recognition the primary objective.

Stations must meet the requirements for emergency evacuation as established by NFPA 101 and NFPA 130. These documents and any other applicable codes shall be used when determining the size of station exit stairs and other vertical circulation elements.

The station design will also be governed by the following factors:

- Passenger volume
- Fire/life safety requirements
- Integration with other modes of transportation
- Local site conditions
- Joint development opportunity

Platform Configuration

All station platforms shall be low level loading type, either center platform or side platform with a nominal 14 inches height above the top of the rail. To enhance security, platform entry points shall be clear of obstructions reducing visibility. Evenly distributed

platform entry points produce system operational benefits. Platform edge pavers with a truncated dome pattern shall be provided and shall be consistent with the rules and regulations required by ADA.

The horizontal alignment at stations shall be tangent throughout the entire length of the platform. The tangent shall be extended beyond both ends of the platform a desired minimum of 75 feet.

Zero grade is desired in passenger stations. Special provisions may be necessary to maintain adequate drainage. The absolute maximum allowable grade through a passenger station shall be plus or minus 1.0 percent. Vertical curves shall not encroach within 82 feet of station platforms.

Platform Size

Station platforms shall be sized to accommodate site specific patronage projections. For platform sizing and means of egress, including emergency conditions, refer to NFPA 101 and NFPA 130.

- Platform widths, unless otherwise specified:
 - Center platform: 18 feet
 - Side platform: 14 feet
- Platform length: 270 feet for a typical station.

Structural Design

Guideway structures that support transit vehicles have the greatest potential for variance in structural criteria due to the vehicle design alternatives available. These include street level passenger loading and high platform passenger loading, multi-articulations and therefore numerous potential curve radii, and either pantograph or rail level electrification.

The axle loads and spacing used for conceptual design are shown in Figure 6-3:

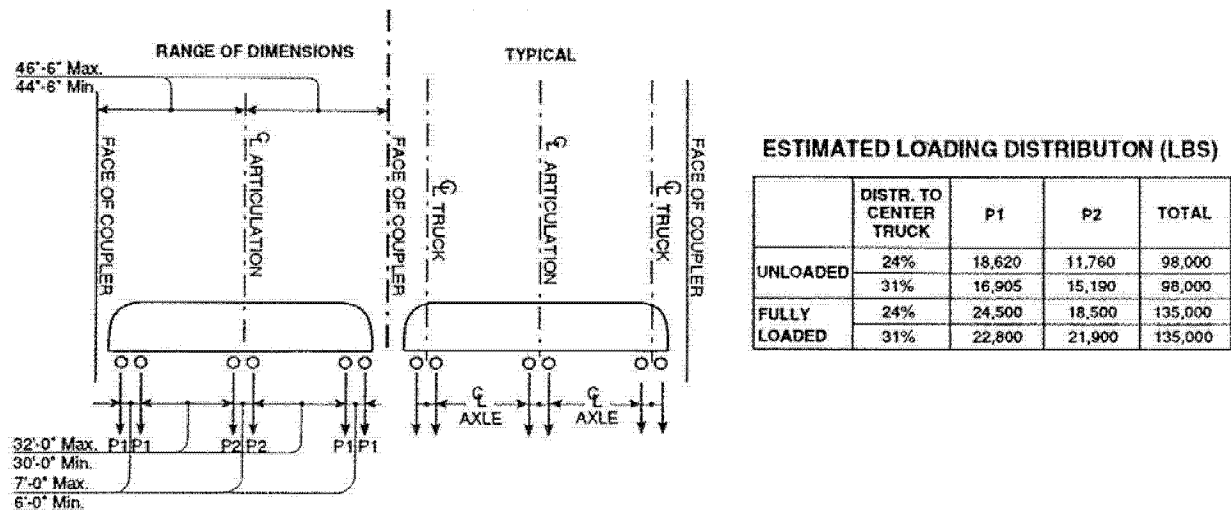


Figure 6-3: Conceptual Design Loading Distribution

The fully loaded 135,000 pound weight of the vehicle is distributed over a bogie (undercarriage truck) span of about 30 feet. The total vehicle coupler distance is about 90 feet.

An articulated vehicle distributes its load more uniformly along the guideway length, tends to conform to the horizontal curvature of the guideway better than one that is not articulated. This reduces the length of its criteria's dynamic envelope and allows the tracks to be spaced more closely together. This has benefits for the guideway girders and piers, especially one supporting two trackways.

The use of continuous steel running rails produces several beneficial guideway structural characteristics. The rails are supported above the guideway girders by concrete plinths normally about 6 inches high. This removes most of the criteria alignment tolerance problems for vertical and horizontal curvature and super-elevation, as well as those caused by concrete creep, shrinkage, short term change in camber, and differential settlement of the foundations.

An additional criteria concern is the potential derailment of a train. It is possible to install guard rails or restraining rails for this problem. Guard rails limit the lateral movement of the train after a derailment, while restraining rails resist the tendency to derail. Owners vary in the usage of these two solutions but most use restraining rails only on sharp curves with no further precautions on more tangent sections. Derailment is therefore one of the criteria design loads for most steel rail systems. This somewhat difficult force concept is shown in Figure 6-4.

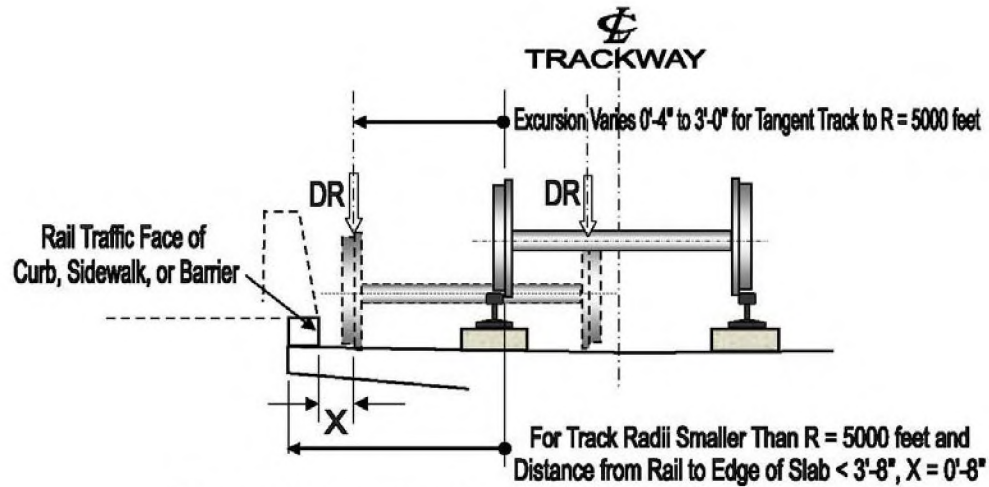


Figure 6-4: Lateral Vehicle Excursion for Vertical DR Load

Guideway girder dynamics enter into the criteria for all moderately high speed transit systems being considered for the Honolulu High-Capacity Transit Corridor. This is mainly a vertical ride comfort criteria that requires the girder to have a period of vibration that will not result in harmonic resonance with the vehicle undercarriage. Due to the usual width of steel rail guideway girders, torsional resonance is not assumed to occur.

During a seismic event, at least one train is assumed to occupy the guideway for either dual or single track guideways. This is because all steel rail, monorails, and maglevs have lateral restraining devices that transmit the seismic force from the vehicle to the guideway.